NITROUS OXIDE: HISTORY AND DEVELOPMENT*

BY

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The discovery of nitrous oxide by Joseph Priestley in 1776 may justly be described as the dawn of anaesthesia. In 1798 the Pneumatic Institute was founded by Dr. Beddoes at Clifton, Bristol, for the treatment of phthisis and other lung conditions by inhalation of gases. Humphry Davy was an assistant at the Institute, and in 1800 he published a book on nitrous oxide, in which this passage occurs:

"As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations where too great an effusion of blood does not take place."

Here we have the first clear and definite mention of the use of nitrous oxide as a general anaesthetic, but it was not until nearly half a century later that this suggestion was actually put into practice. This brings us to one of the saddest periods in anaesthetic history, for by ignoring the work of one of its greatest sons this country lost the proud distinction of giving general anaesthesia to the world a quarter of a century before Wells and Morton. I refer to Henry Hill Hickman, who was born in 1800, the very year in which Davy made his observation. At the age of 20 he obtained the M.R.C.S., and practised at Ludlow in Shropshire. Impressed by the sufferings of those upon whom he was called to operate, he resolved to seek some method of alleviating their pain by rendering them unconscious before operation. He experimented on animals by asphyxia, nitrous oxide, and carbon dioxide. He then operated on animals, and met with considerable success. He decided that if his methods were applied to the human subject they would become of the greatest value to mankind in making painless the performance of major surgical operations. The profession in England derided this work, and condemned it as dangerous and useless. Disheartened, he resolved to lay the matter before the Royal Academy of Medicine in Paris; little was done, only Larry (Napoleon's surgeon) showing any belief in the work. The young surgeon, disappointed and hopeless, returned to England to die at the early age of 29. In 1930 a deputation from the Anaesthetic Section of the Royal Society of Medicine, mainly at the instigation of Dr. Hughes, visited Ludlow, and attended a religious service and the unveiling of a tablet to commemorate this early pioneer's work.

The discovery of ether about 1830 rather ousted nitrous oxide, and it was not until 1844 that H. Q. Colton, who is described by a writer as an itinerant lecturer, gave an entertainment at Hertford, Connecticut, where people in the audience inhaled nitrous oxide for its exhilarating effect. Horace Wells, a dentist of that city, who was present, noticed the freedom from pain that attended the accidental injury of one of the subjects. He was greatly impressed, and persuaded Dr. Colton to give him gas on the following day, while Dr. John M. Riggs, another dentist, was invited to extract a tooth. The experiment was a complete success, and on recovering Wells declared that he had had no pain whatever. He then, in conjunction with Riggs, began to use the gas freely in his practice. Later on he gave a demonstration at Massachusetts General Hospital, but the facepiece was removed too soon, and the patient gave a yell, whereupon Wells was hissed out of the theatre as an impostor. This is quite easy to understand when one reflects that the method of administration at that time was to fill a bladder with the gas, which was inhaled by means of a pipe through the mouth, while someone held the nose. Wells died in 1848, having severed a vessel in his arm and taken ether to render death painless.

Bigelow states that in 1848 a patient had her breast removed under nitrous oxide gas, which was given through a valve mouthpiece and a flexible tube leading through a bladder to two large copper reservoirs filled with gas. He states:

"After several inspirations the patient's lips and the most vascular part of the tumour began to assume a purple colour. She remained quiet, however, and in a short time was evidently insensible."

In 1875 Dr. C. A. Brackett kept a patient under nitrous oxide for about thirty minutes while Dr. Squier removed a cancer of the breast. Dr. Brackett describes it as a "grand success." The patient was not conscious of the operation, and he adds, "I believe this is the first achievement of the kind in New England." (He obviously was not aware of Bigelow's experiment in 1848.)

MANUFACTURE AND CONTAINERS

During all this time nitrous oxide had to be prepared just before the operation, and was kept in a sort of gasometer, but I have obtained a short description of what happened in those days from Mr. H. S. Coxeter, a great-grandson of the original Coxeter. He says:

For some of the earliest cases of nitrous oxide anaesthesia, both in the laboratory and in private dental practice, the gas was supplied in ox bladders, the patient inhaling the gas through the outlet tap, while his nose was pinched by one assistant and the bladder was squeezed by another. It is true that these early cases were mostly of an experimental nature, although slight operations were often performed under a sufficiently deep, but sometimes unexpectedly short anaesthesia. These bladders of nitrous oxide were regularly supplied by J. Coxeter and Son for use at the old University College Hospital opposite their premises. The gas was made by heating ammonium nitrate in glass laboratory retorts over a Bunsen burner and collecting it under water, no further washing being then considered necessary. The interest taken by the surgeons in the new anaesthesia, and its immense popularity among the students, due largely to the amusement caused by the hilarious excitement exhibited by the patient under this crude method of administration, pointed to a great future for "laughing gas."

Delivery by messengers carrying bundles of bladders like a toy balloon seller was obviously impracticable, and Mr. Coxeter quickly had some cylinders made of wrought iron tubes with welded tops, bottoms, and seams. Into these the gas was pumped by hand, with a great expenditure of time and energy, and the gas sold according to the varying amount it had been reasonably possible to pump in. As the demand increased it became obvious that a more rapid method of manufacture and filling was necessary, and a factory was started in a covered yard, in which a gas-engine-driven compressor was installed. The heating of the ammonium nitrate was now done in cast iron retorts, into which melted ammonium nitrate was poured through a funnel and the orifice plugged securely. The retort was then heated over a gas ring, and the nitrous oxide bubbled through into Woulfe's bottles containing a solution of caustic potash, entering a small gasometer, from which it was pumped into the cylinders.

For a time there was a state of considerable tension in the workshop, as no one quite knew what might or might not happen either during the manufacture of the gas or the filling of the cylinders; the latter, although extremely heavy, had a nasty habit of developing a sudden and alarming leak at one of the seams. Also the ammonium nitrate, not having the high degree of purity obtained later, was somewhat erratic in its behaviour, and upon the appearance of white fumes in the Woulfe's bottles, hose pipes were turned on to the retort with all speed. Sometimes even this was ineffective, and as the gas came off with ever-increasing force and fury, it was left in sole possession of the workshop, and the workmen anxiously awaited events outside. Improved methods of manufacture have been in use for some years, and the gas is now delivered in a very pure state. The unsatisfactory iron bottles were replaced by drawn steel seamless cylinders. Cast brass valves were replaced by those of a tougher alloy, stamped or drop-forged.

The steel cylinders were very heavy, and after the war I endeavoured to get permission to use some cylinders, made, I believe, of aluminium, which had been used by the Air Force to carry oxygen, and were very light. There were several objections, the chief being third-party risks (injury to the workmen when filling them), and we were

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not allowed to use them. Now, however, new steel has been evolved known as vibrac steel. This is a nickel, chromium, molybdenum, and manganese alloy ; it is light and strong, and apparently conforms to all the tests that are required by the Government.

GAS AND OXYGEN IN PROLONGED ANAESTHESIA

Colton revived nitrous oxide in 1863, and in 1867 was able to give a record of 20,000 cases. In 1868 a demonstration was given at the Dental Hospital in London by Dr. Evans, a dentist from Paris, and after this the use of the gas spread enormously. In 1868 Andrews published accounts of a number of cases in which he had obtained a non-asphyxial form of anaesthetic by using oxygen with nitrous oxide.

In a little manual on nitrous oxide, or "laughing gas," by F. R. Thomas, published in 1870, we find some diverting reading. Among other things we are reminded that Faraday liquefied gas in 1822. The manufacture of nitrous oxide before the operation is described in very great detail. The author says that in purifying the gas it is unnecessary to use anything but a solution of the sulphate of iron in one bottle and fresh water in the other two. Some chemists recommend the use of caustic potash in addition, for the purpose of neutralizing any chlorine gas that may be present.

"In my judgement, however," says F. R. Thomas, "the use of these chemicals is superfluous, as I have found by experience that the action of the gas is precisely the same, whether it is washed through those solutions or whether it is washed through fresh water and allowed to stand a sufficient length of time (about 5 or 6 hours) for the water in the gasometer to absorb any impurities that may have passed over with the gas."

How different that is from present-day conditions, when the gas is most carefully washed and presented to anaesthetists free of water and, as is described by the suppliers, as non-freezing gas! In another place Thomas says:

"I am therefore confirmed in the opinion that after nitrous oxide has been kept over four or five days it becomes very much deteriorated by the absorption and loss of oxygen."

It would appear, therefore, that this Dr. Thomas had very definite ideas on the subject of nitrous oxide, and it is interesting to see how in the course of time the opinions that he then expressed have been considerably altered.

Clover and Coleman first gave continuous nitrous oxide through the nose, but it was not used for prolonged cases until somewhere about 1895, when Herbert Paterson began giving nitrous oxide through the nose for prolonged dental cases. Bellamy Gardiner, working quite independently of Paterson, produced papers shortly afterwards showing that nitrous oxide and oxygen could be given for lengthy periods. Paterson used to go round the country giving demonstrations of prolonged nasal gas for dental work, and he has himself told me that on several occasions he gave these dental gases for well over an hour. Paterson soon took up surgery, and the administration of prolonged gas and oxygen was carried on mainly by Bellamy Gardiner. Just previously Sir Frederick Hewitt had produced his gas and oxygen machine, and it was with this machine, or an adaptation thereof, that Bellamy Gardiner worked. Hewitt's machine did not permit of rebreathing, and so it missed one of the essential points of gas-oxygen anaesthesia. Later on Harvey Hilliard introduced a method of passing a catheter through the nose into the post-nasal space, through which he delivered gas, and obtained a prolonged anaesthesia for dental work.

Up to this time gas and oxygen had not been used extensively in this country, and it was the advent of Teter and Gwathmey to an international conference in 1912 that gave a much-needed impetus to and interest in the method. Teter gave a demonstration at Guy's in 1912, and after that Chaldicott and Page tried to popularize gas and oxygen, but interest in the anaesthetic was very lukewarm. Soon after the beginning of the war I obtained from Dr. Gwathmey one of his machines, and began to use the method. In October, 1917, I read a paper before the Medical Society of London on "Experiences of the Use of Nitrous Oxide and Oxygen with Rebreathing in Military Surgery." It is interesting in the light of subsequent development to read the criticisms that were levelled at it, but that is past history, and nowadays most anaesthetists give gas-oxygen-ether.

It may be of interest to note here that very soon after the publication of this paper the War Office demanded several machines—machines which were being made by Coxeters and sold as Boyle's gas-oxygen-ether apparatus. Coxeters were unable to supply these needs, most of their staff having been called up, and so the War Office had the machines made by Siebe Gorman and Co., and I well remember being sent there to pass them as fit for use at the front. Machines as made then were very crude compared with the finished article to-day, but on some occasions I had to pass as many as three dozen.

The main points which came out during the discussion of my paper before the Medical Society of London were: (*a*) that there was hardly any rise of temperature after an operation under gas-oxygen with a little ether, as compared with ether or chloroform alone. Moreover, as the patients were conscious very soon after the operation had finished, it was obvious that the work of the nursing staff was greatly lessened ; (*b*) that severely wounded and septic men did much better under gas and oxygen than under ether or chloroform.

After the war the development of gas-oxygen-ether for civil practice became essential. The endotracheal administration of ether had been in vogue since 1912, and it now appeared that we thought it advisable to try the endotracheal administration of gas-oxygen-ether. This met with great success, and to-day the endotracheal administration of gas-oxygen-ether is my routine for abdominal operations. My reason for this is that a very quiet abdominal wall is obtained, and indeed in a good gas the relaxation of the abdominal wall is almost, if not quite, equal to that obtained by a spinal anaesthetic.

Many alterations and improvements have been made in the endotracheal method. The most important is perhaps the one advised by Dr. Magill, who passes a soft rubber tube, about the size of one's finger, down the nose and into the trachea. Then, if necessary, he can pack the fauces, and so prevent any blood from being inhaled. When this tube is in position gas and oxygen alone will suffice for most operations. There have, of course, been other alterations, but this is probably the most important. Another method, and one which is required by some throat surgeons, is to introduce two catheters into the trachea, the idea being that if the fauces are then packed the anaesthetic can be given by one tube while the other tube takes off the expired air.

No paper on nitrous oxide would be complete without the mention of E. I. McKesson of Toledo, Ohio, who has produced more apparatus and has probably done more work on nitrous oxide than almost anyone in the United States of America. McKesson, on occasions, practises what he calls "secondary saturation" with gas to produce relaxation. When I saw him do this it was an alarming sight. It consisted of giving gas until the pupils were widely dilated, the colour was grey, and the patient looked like death. Then the lungs were distended with oxygen, and gradually the colour returned to pink. "That is primary saturation," said McKesson, and then he proceeded to do it all over again—a method I am glad to have seen, but not one that I am prepared to teach to students. McKesson is a very able anaesthetist, and has certainly produced a most excellent machine.

The next development in gas-oxygen-ether anaesthesia was its use in midwifery. In 1921, when I was in America as the representative of the Royal Society of Medicine, I found that they were giving gas-oxygen for childbirth. On my return to this country I endeavoured to follow their example, but for some time obstetricians were rather shy of it. At last one of them took the plunge, and since then he and others have been using it. The method is to administer gas with each pain, and, briefly, only to use ether at the end of labour, just before the child is born. The addition of a little carbon dioxide used with discretion and care enables one, to some extent, to shorten the labour, to produce the child a rosy pink, and, *I think*, to shorten the time for the delivery of the

afterbirth. This method is useful in hospitals, but it is not suitable in general practice in outlying districts of the country. Should the time ever come when all the women of this country are confined in institutions, it will then become possible to use this method on a large scale. At the moment, however, although we are supplied with comparatively light cylinders, the method is impracticable for country districts because there must be one person to give the anaesthetic and another to deliver the child.

In the new surgical block at St. Bartholomew's Hospital there has been installed, at my suggestion, an equipment by which gas-oxygen and carbon dioxide is stored in the basement, and is then taken by a series of pipes to the five anaesthetizing rooms and to the five theatres; it is thus perfectly easy to give gas-oxygen or carbon dioxide by simply turning a tap, and we have no cumbrous cylinders about the theatre.

In conclusion, I should like to thank my friend Dr. Eric Worsley Gandy for the loan of the valuable collection of books on the early days of nitrous oxide, and also Mr. H. J. Bennett of Coxeter & Son for his very interesting information.

FORMATION OF A VOLUNTARY HOSPITALS' COUNCIL FOR LEEDS

For a good many years negotiations have been carried on between the Boards of the General Infirmary at Leeds, the Hospital for Women at Leeds, and the Leeds Maternity Hospital, with a view to promoting co-operation between the three institutions. As a result of these a Voluntary Hospitals' Council has been formed, some details of which are given below.

First, however, something must be said concerning the separate development of the three hospitals, and the scope of their work at the date when the newly constituted council became operative on January 1st of this year. Those who are responsible for the administration of the medical charities of Leeds, and certainly those who are concerned in medical education and in research, have always regarded it as a fortunate thing that, apart from certain special departments, most of the work has been concentrated in that institution the correct name of which is the "General Infirmary at Leeds," not the "Leeds General Infirmary," and this is indeed right when one considers the large area from which the hospital draws its patients. Founded in the year 1767 by the first William Hey, it carried on its work in a succession of centres until the present building—one of the first in the country to be erected on the pavilion system—was opened in the year 1868. In 1894, under the chairmanship of Mr. Benson Jowitt, the building was considerably enlarged, and after the war the extensive additions and alterations, which arose from the inspiration of Mr. Charles Lupton, were completed. Many years ago there used to be an eye institution in Leeds, but this was taken over by the Infirmary, with some necessary adjustment of the staff. For some time the dual posts of ophthalmic and aural surgeon were held by the same honorary officers, of whom there were two. These departments, however, were separated about twenty-three years ago, and there are now two ophthalmic surgeons and two surgeons in charge of the ear, nose, and throat department.

Until 1885 students of medicine in Leeds were dependent on their association with private practitioners for experience in midwifery. At this time a new honorary post was instituted, and the gynaecological and obstetric department came into existence. A certain number of beds was allotted to the gynaecological work, and this also had an out-patient department, which rapidly increased in size. The work of organizing the new extern maternity department was most ably carried out by the newly appointed resident obstetric officer, the late Dr. O. Croft, to whose work the School of Medicine owes a great debt. There was no accommodation for in-patient obstetric work; it was very exceptional for a woman to be delivered within the walls of the Infirmary. The relation of the Infirmary to the Hospital for Women and Children deserves notice. The latter institution had been in existence for many years, and was not associated with the School of Medicine. Under the chairmanship of the late Mr. Fred. Spark a new hospital was erected, and some beds were set aside for the delivery of women who required hospital treatment. The accommodation in the General Infirmary for children, and especially for those suffering from medical as contrasted with surgical ailments, had been ridiculously inadequate for many years. The writer of these paragraphs recalls that the sole accommodation for this class of patient in 1883 constituted three cots in the female medical ward. By an arrangement with the Hospital for Women and Children it was agreed that its title should be changed to the Hospital for Women, that it should cease to admit children, and that it should undertake both the extern and the limited in-patient maternity work, while the increase in the available beds at the Infirmary would make it possible greatly to extend the accommodation for medical children. The Leeds Maternity Hospital has had a wonderful development, both in respect of rapidity and efficiency, and some time ago it was deemed right that it should take over all the work in connexion with the extern and intern maternity departments. The University interested itself in the matter, and now students have considerable facilities for gaining experience in maternity work.

These details have been given to make clear the state of affairs which has happily developed in Leeds, and which has made it possible, without friction, to arrange for intimate co-operation between, and for a partial fusion of, these three institutions, while leaving to each a large degree of autonomy. There came into operation on January 1st of this year the Leeds Voluntary Hospitals' Council. This is composed of six representatives of the Board of the General Infirmary, and three each of the Hospital for Women and of the Maternity Hospital, and it also includes every member of the honorary staff of the three institutions, together with the warden of the dental department and two other representatives of the honorary dental staff. Thus there is perpetuated the happy state of affairs which has always prevailed at Leeds: that the honorary staffs are fully represented on the Boards of all the institutions, though with some restriction as to voting powers, The duties of the council will be concerned with questions of policy, such as those dealing with extraordinary capital expenditure, alterations in the relative proportion or character of the work to be undertaken by the three component institutions, and generally any questions which may be referred to it by any of the three Boards concerned. At present it is arranged that all the gynaecological work shall be done at the Hospital for Women, all the maternity work at the Maternity Hospital, and everything else at the General Infirmary. The honorary staffs of the three hospitals are combined to form one "Faculty." The honorary staff of the Infirmary has always had this title, and it is one which is jealously held. When it was suggested a good many years ago that the term should be limited to the Faculty of Medicine of the University this was not agreed to. The "Faculty of the Infirmary" was sacrosanct! Among other duties this joint Faculty will have the election of all the members of the resident staff in its hands, and in the future a great many matters will be referred to it by the three Boards concerned.

Perhaps one of the most important considerations in connexion with the formation of the council is the method of election of the members of the honorary staffs. This is to be in the hands of the lay representatives of the council—twelve in number, it will be remembered—together with six others who are not members of the Boards of any of the hospitals, and one-third of whom shall retire annually, and two medical members appointed annually by the council of the University of Leeds. Uniformity as to the qualifications necessary for all candidates for honorary posts has also been secured, and the conditions which have for long prevailed at the Infirmary will apply in future to all the three hospitals. These are that assistant physicians and physicians must be graduates in medicine of a university of the United Kingdom and Members or Fellows of the Royal College of Physicians of London; and that all assistant surgeons and surgeons must be Fellows of the Royal College of Surgeons of England.

It is confidently expected that this scheme of co-ordination will be attended with increased efficiency in the working of the three hospitals, and will enhance the reputation of Leeds as a teaching centre.